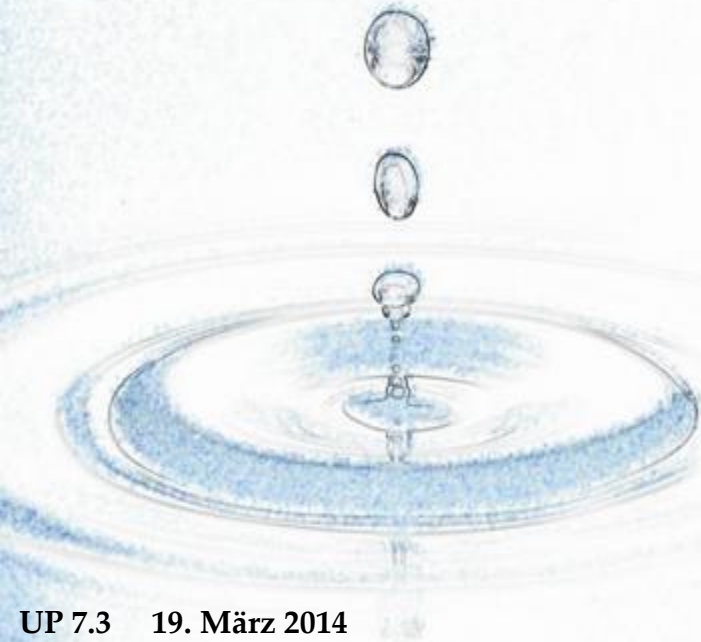


Probing soil moisture

by cosmic ray induced
neutron showers



Markus Köhli

U. Schmidt
AG Dubbers

Ruprecht-Karls-Universität
Heidelberg



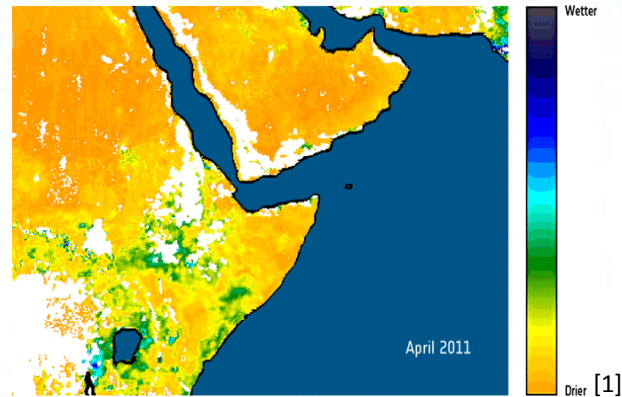
in collaboration with:

Martin Schrön

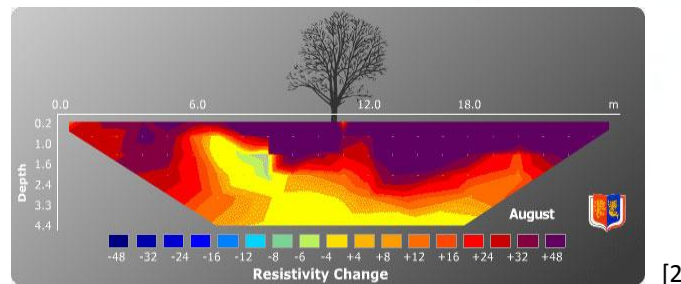
Helmholtz Center for
Environmental Research
Leipzig



Present: The measurement of moisture



via
satellite remote sensing
(optical, microwave)

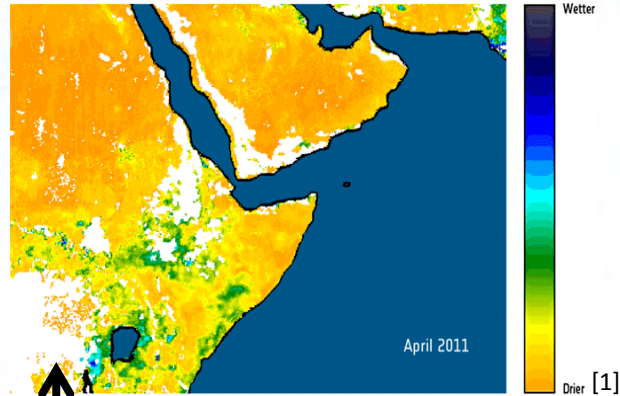


via
local techniques
(electrical resistivity, capacitance, etc)
(even neutrons...)

[1] ESA SMOS (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS/Horn_of_Africa_drought_seen_from_space)

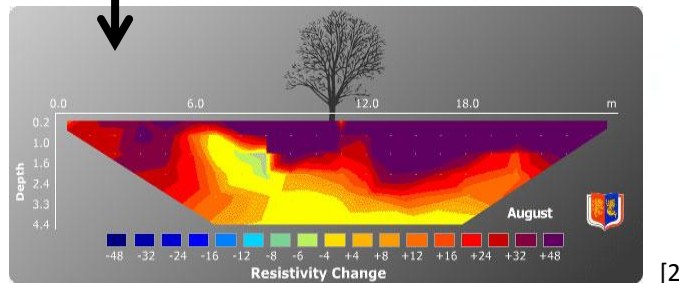
[2] The Clay Research Group (<http://www.theclayresearchgroup.org/images/ert.jpg>)

Present: The measurement of moisture



via
satellite remote sensing
(optical, microwave)

No (affordable)
technique in between



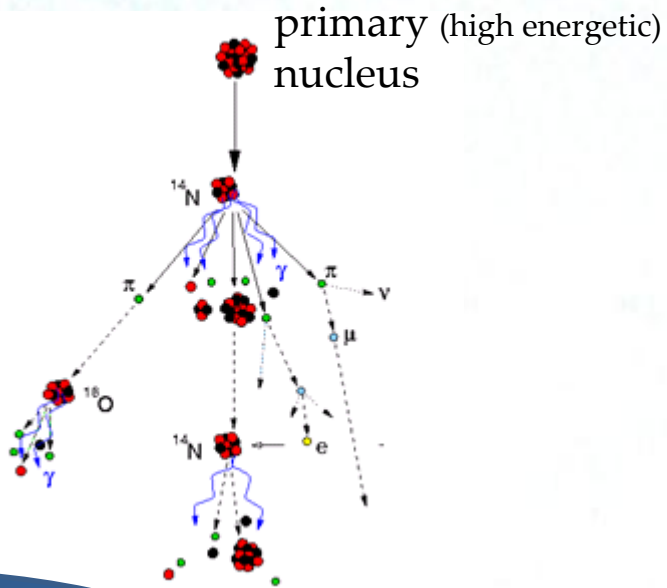
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[1] ESA SMOS (http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS/Horn_of_Africa_drought_seen_from_space)

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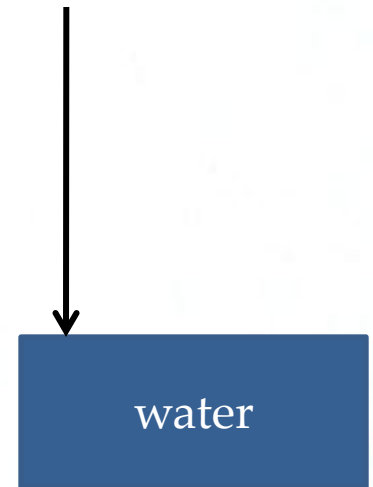
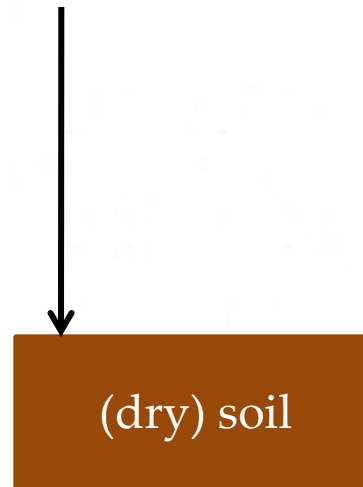
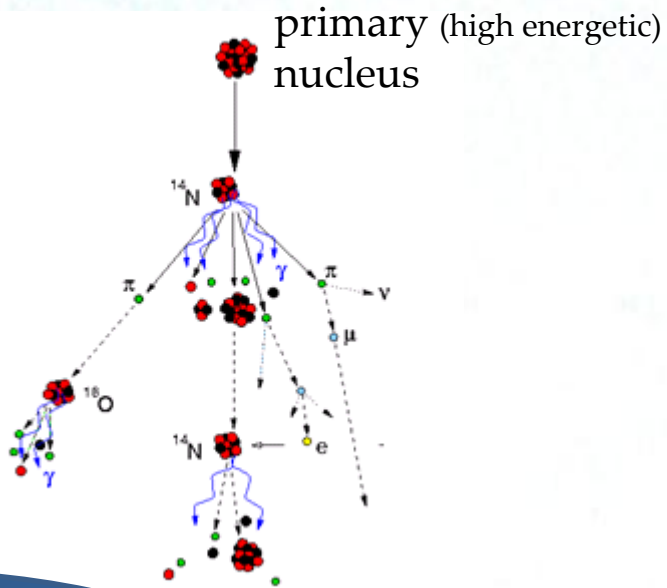
Can neutrons of the cosmic radiation...

...be used to probe the moisture content of the soil ?



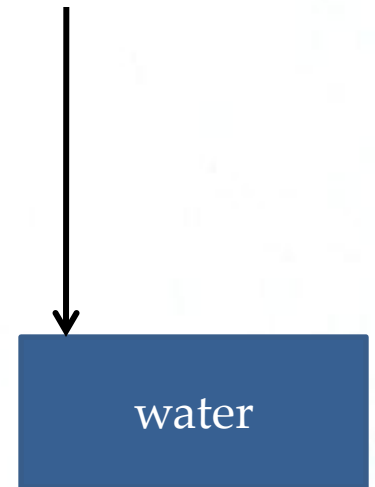
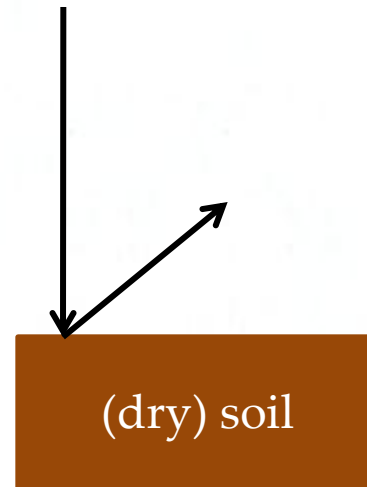
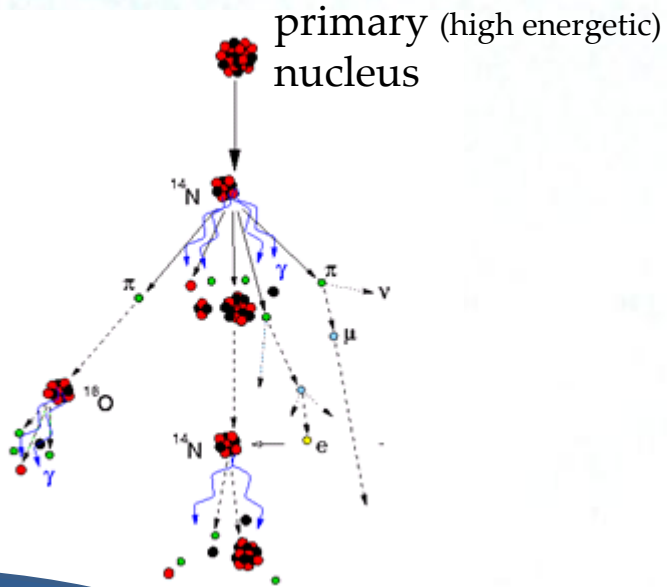
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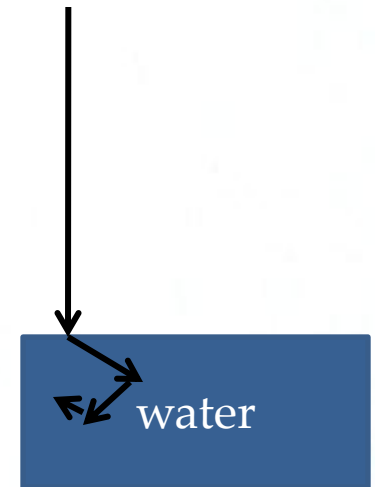
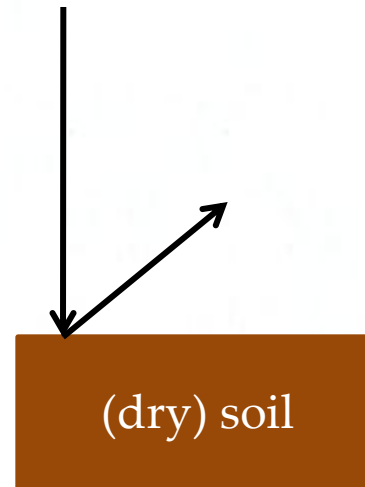
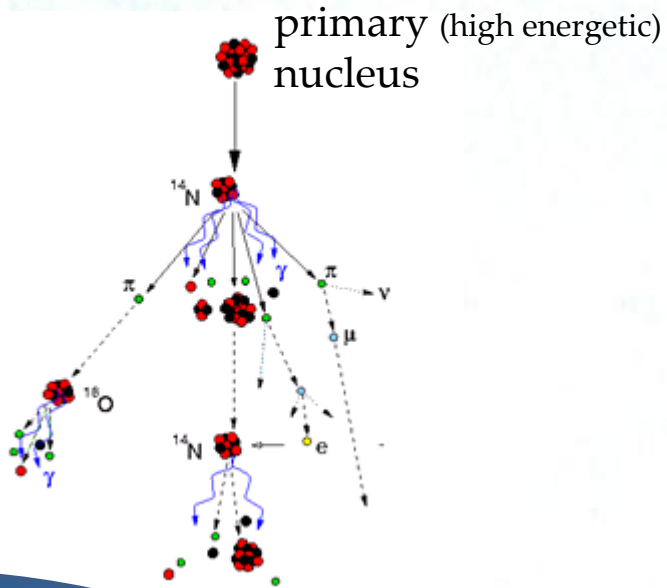
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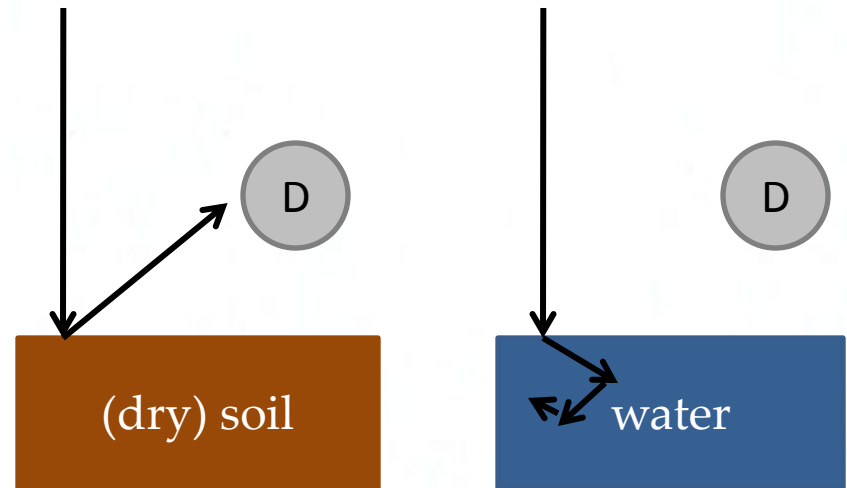
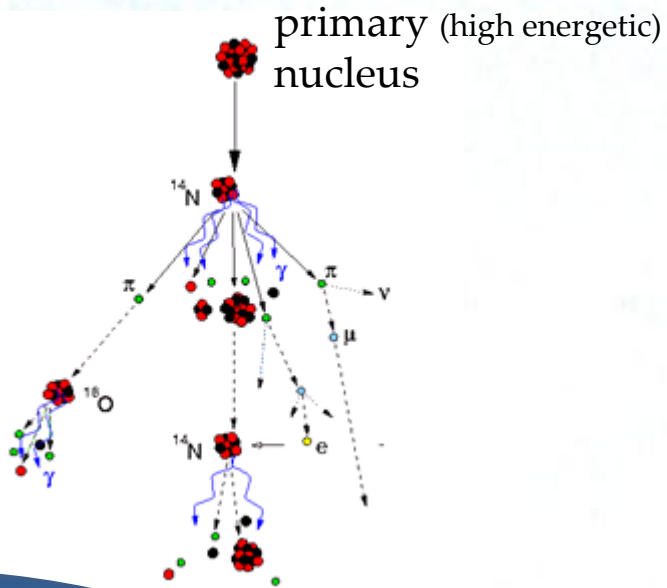
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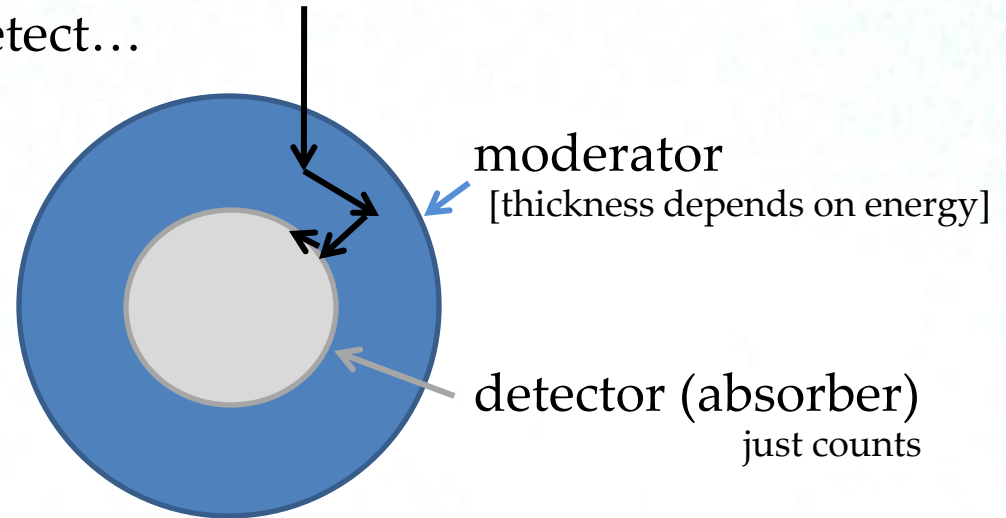
Can neutrons of the cosmic radiation...

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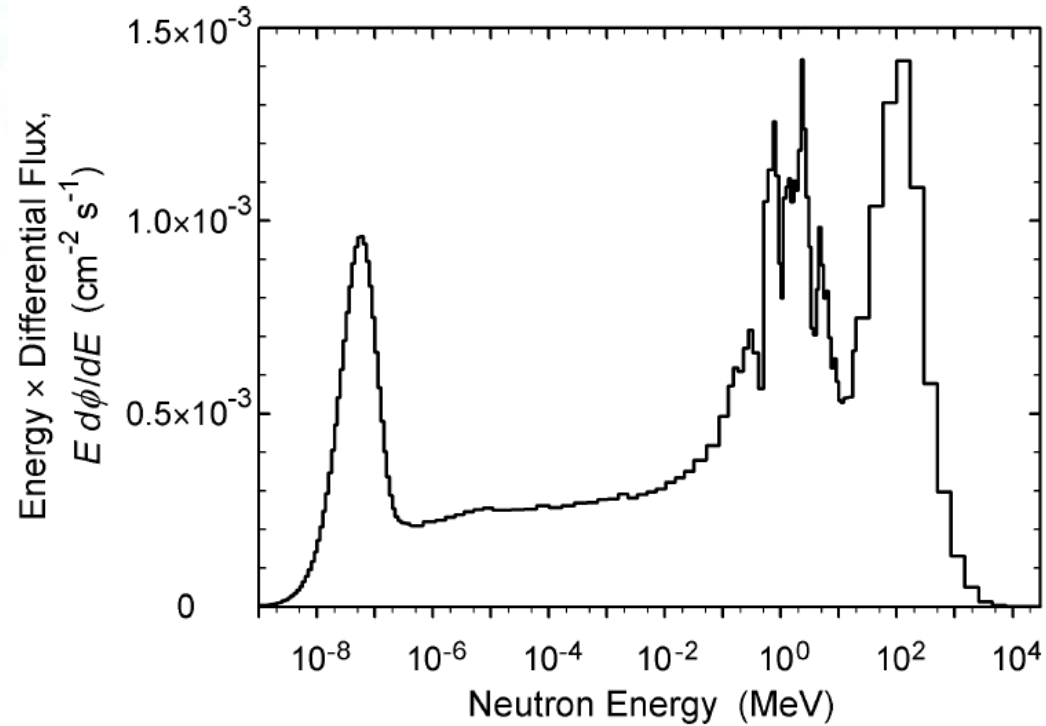
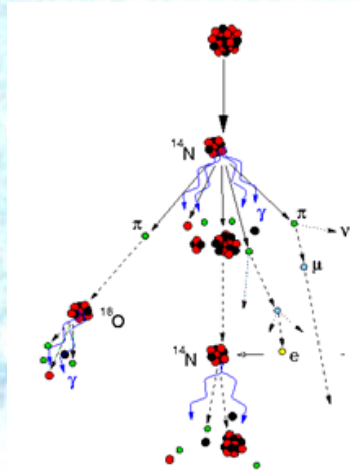
Why a Monte Carlo simulation?

Neutrons are difficult to detect...

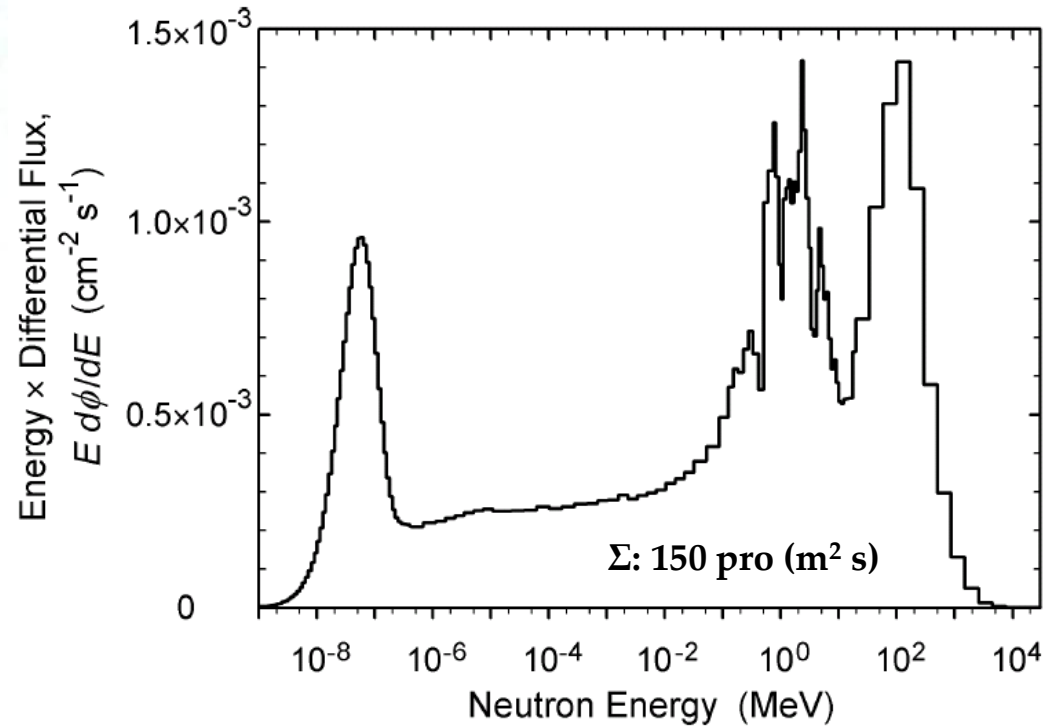
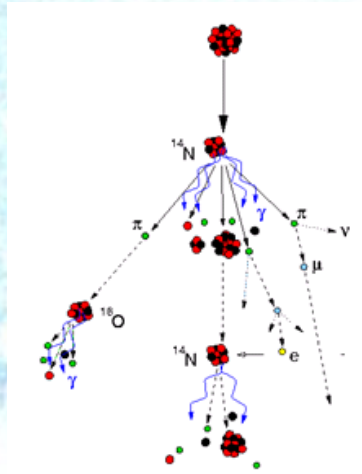


...with bad energy and angular resolution

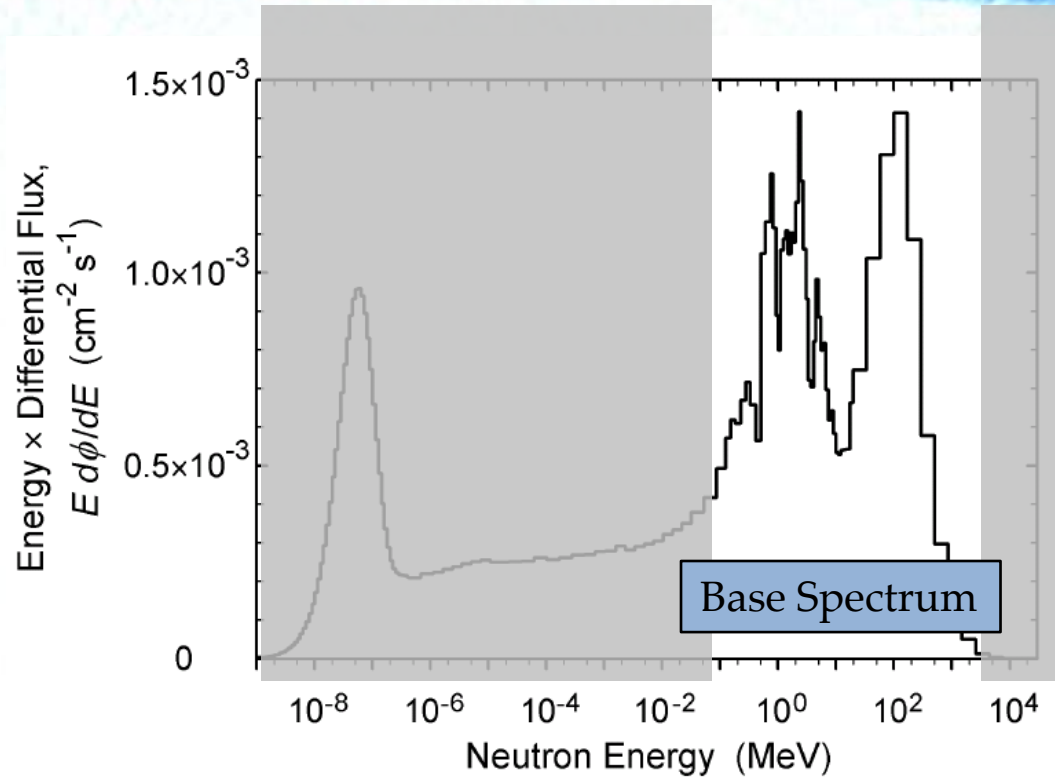
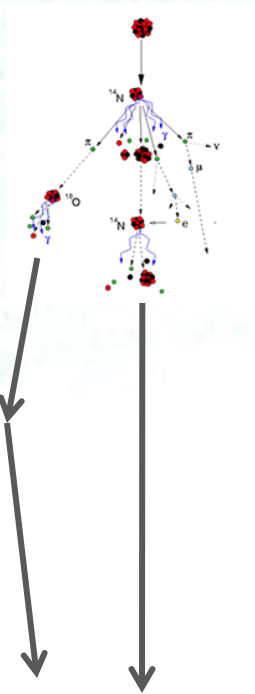
The cosmic neutron spectrum



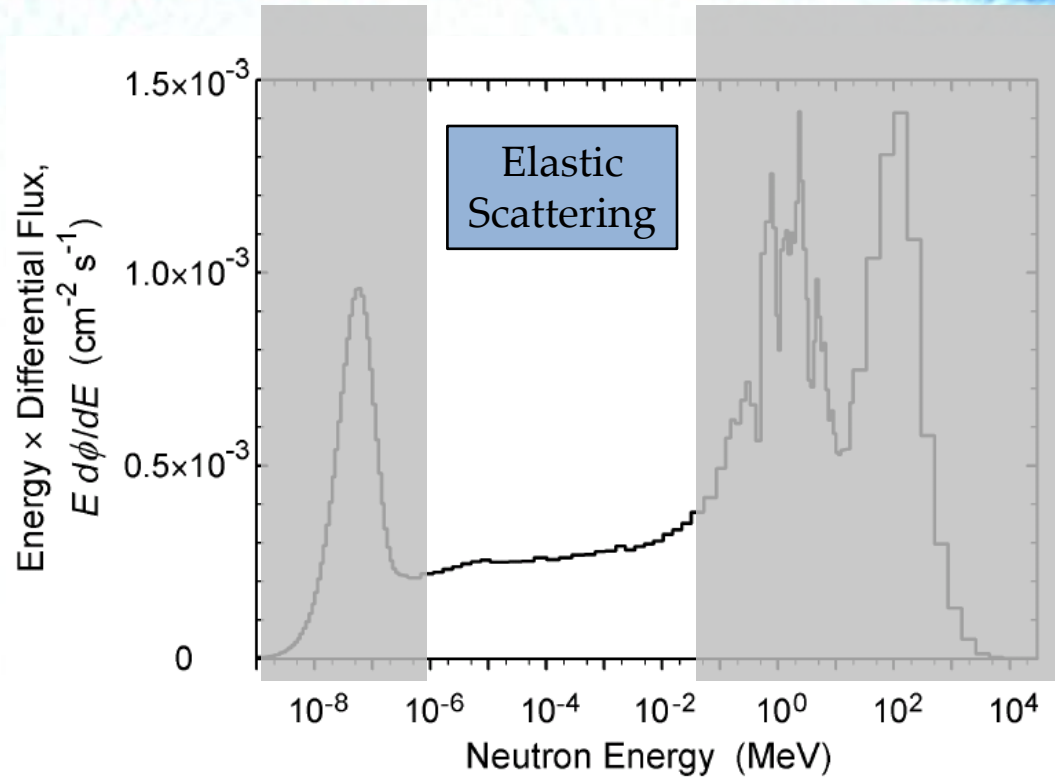
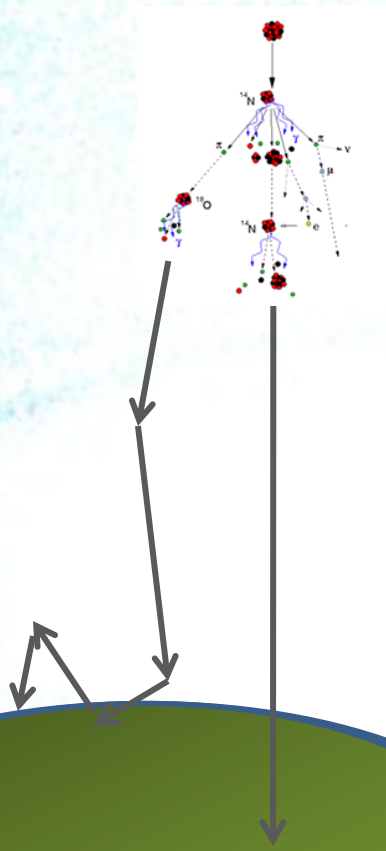
The cosmic neutron spectrum



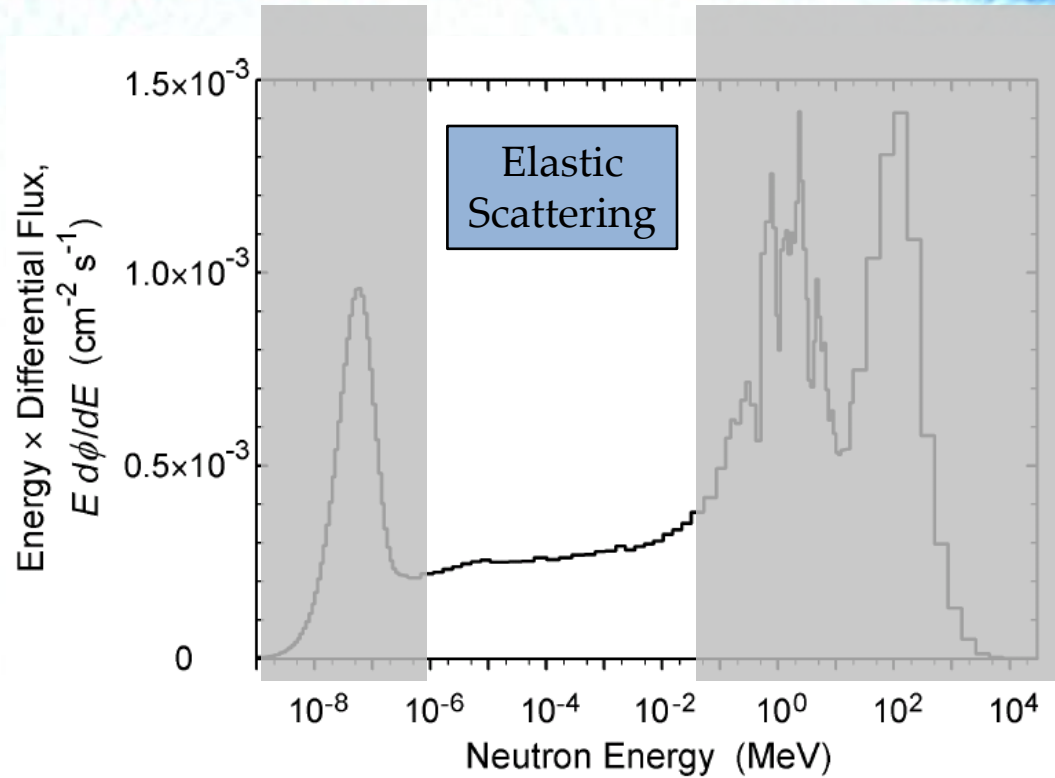
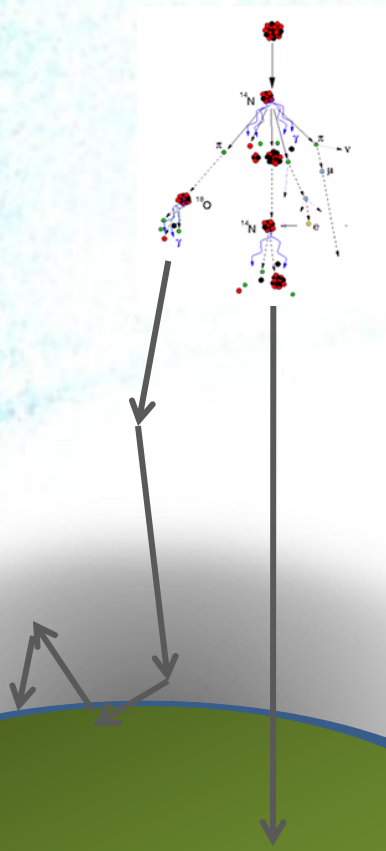
The cosmic neutron spectrum



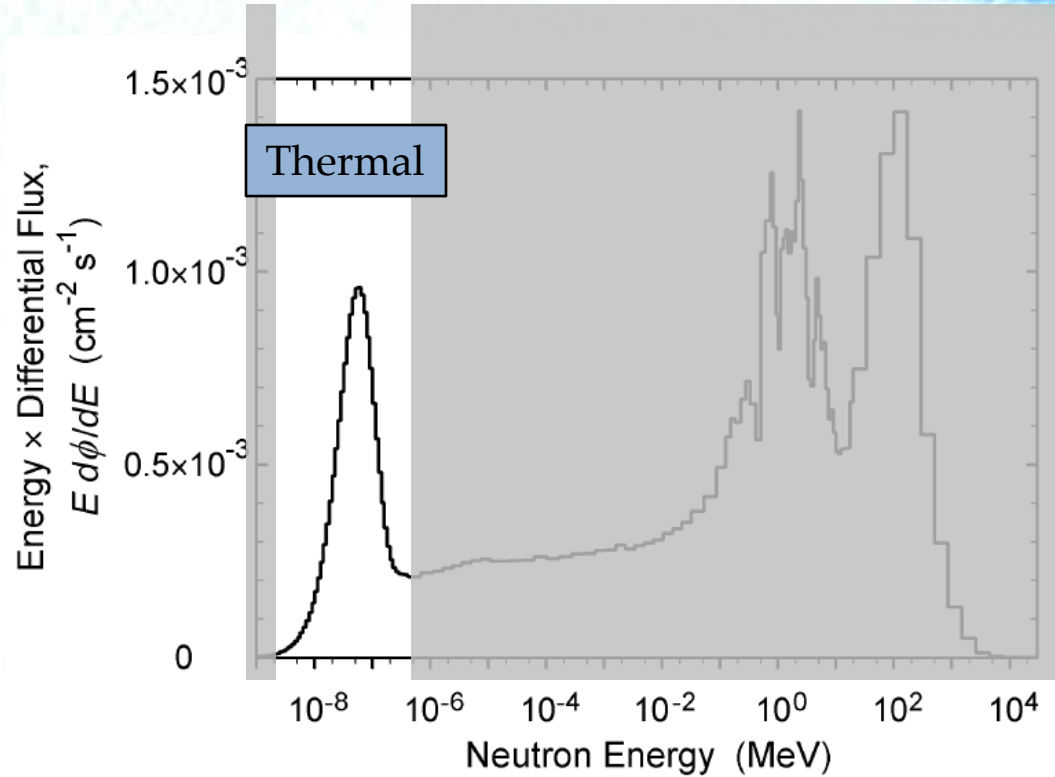
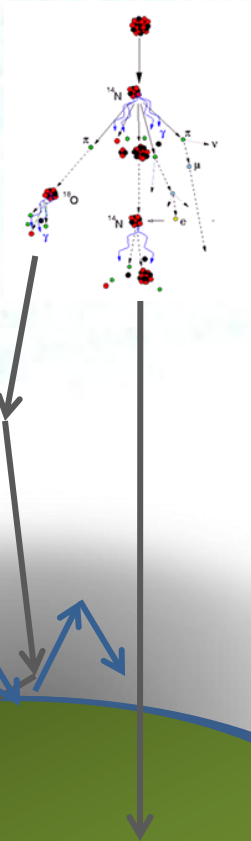
The cosmic neutron spectrum



The cosmic neutron spectrum

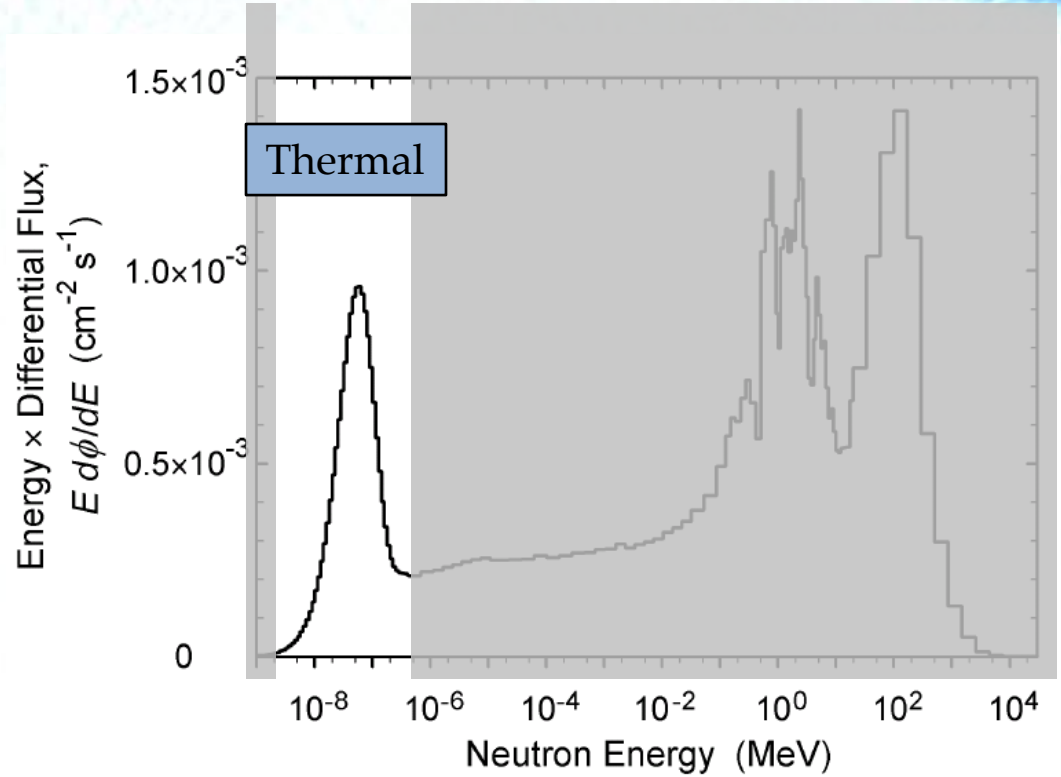
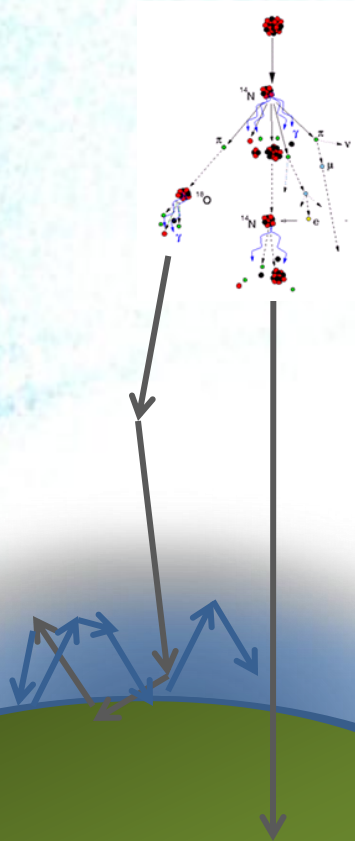


The cosmic neutron spectrum



$$E = O(k_B \cdot 300\text{K})$$

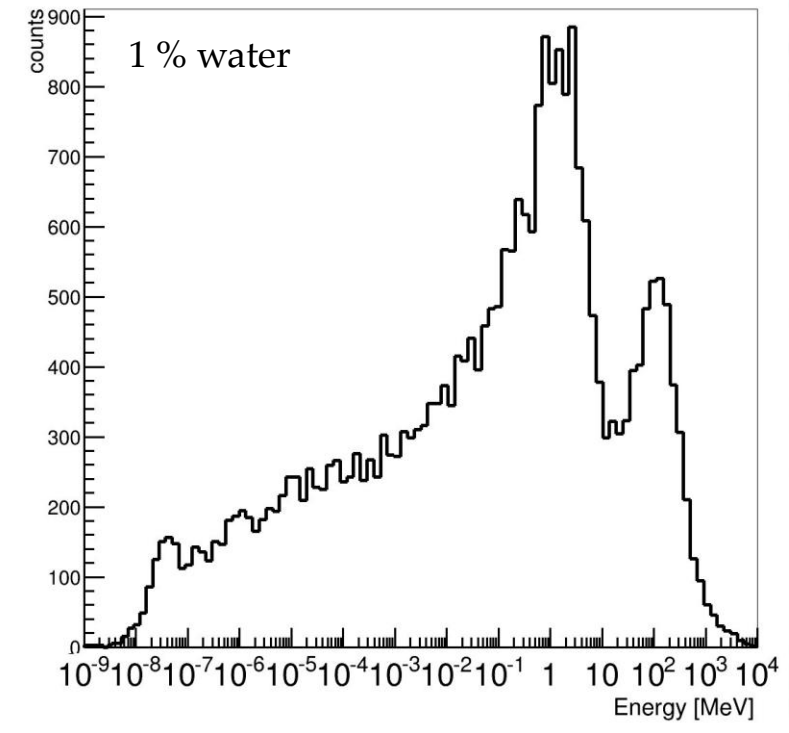
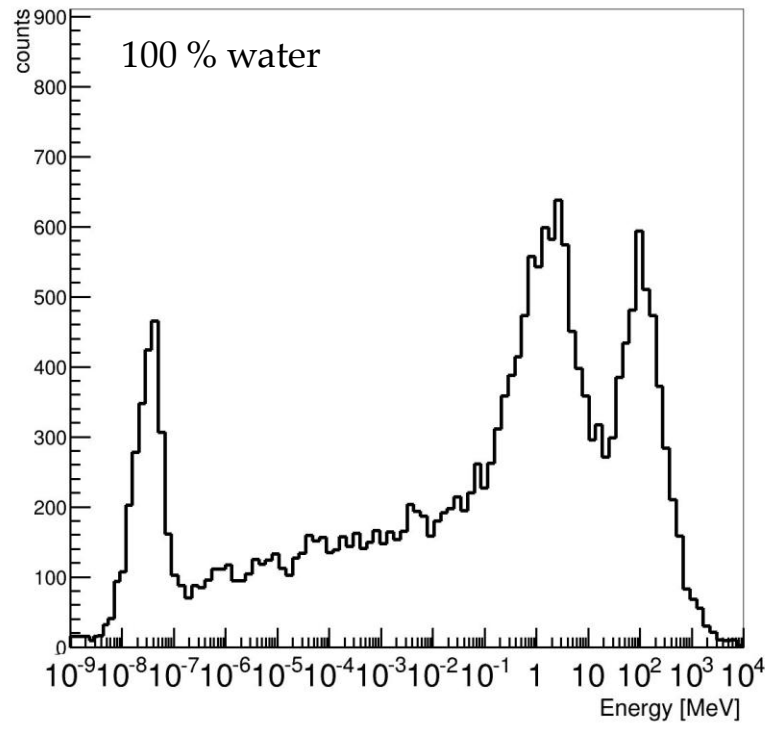
The cosmic neutron spectrum



$$E = O(k_B \cdot 300K)$$

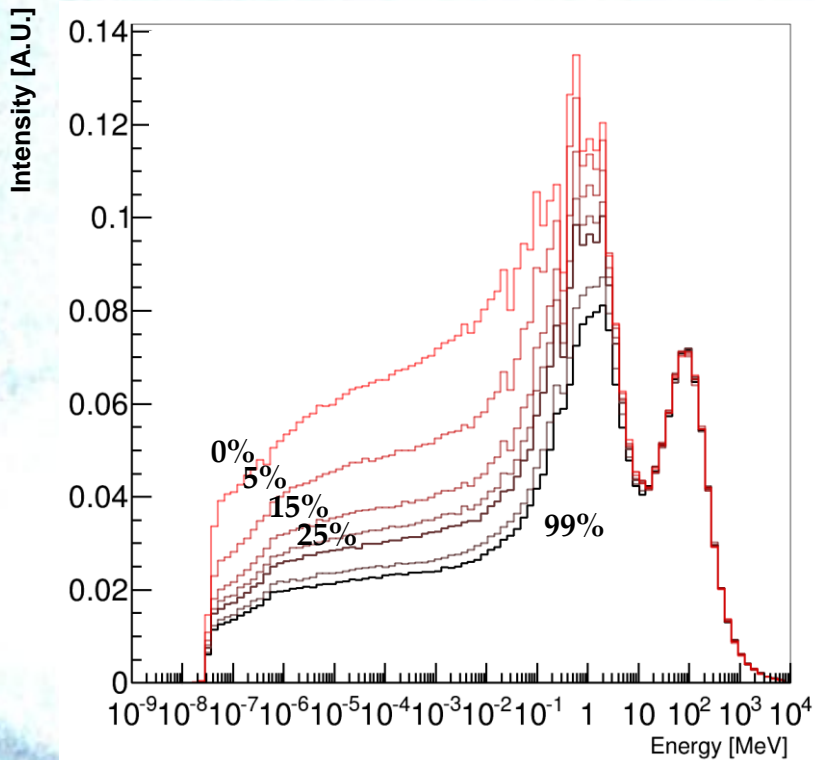


Neutron spectra examples



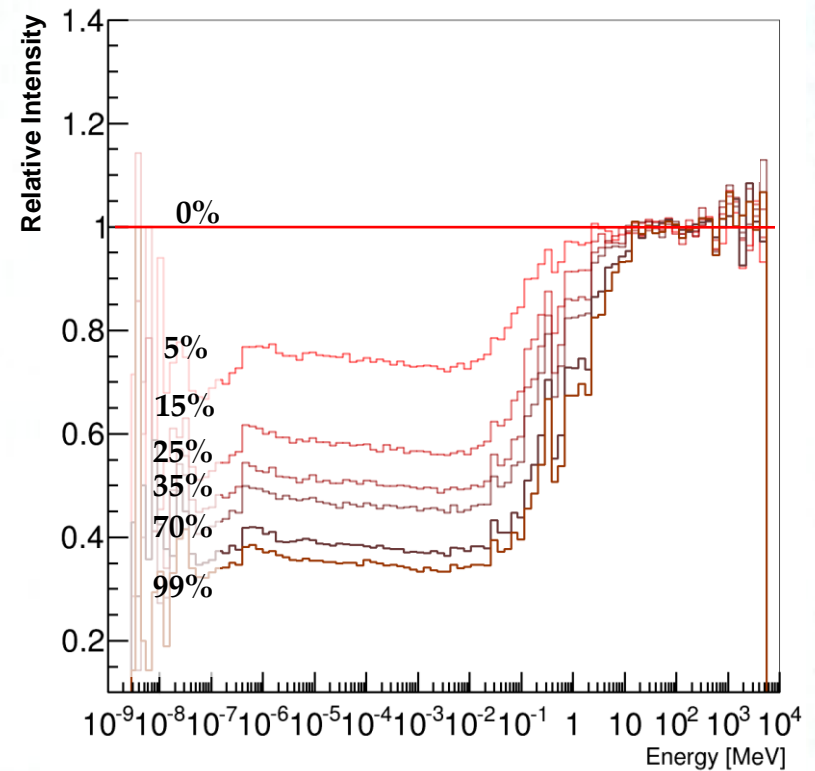
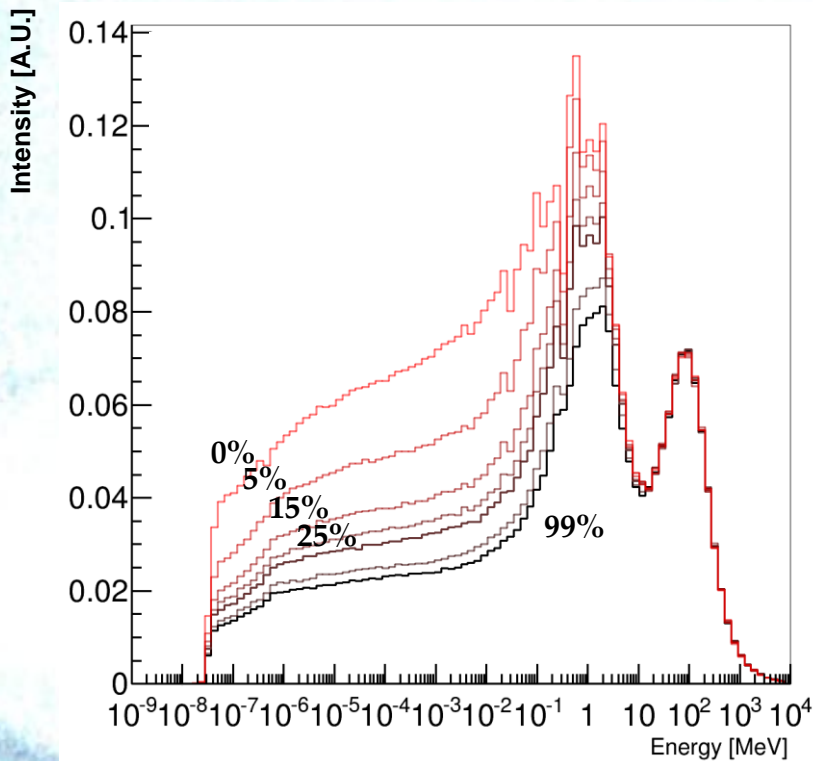
Neutron spectra for soil of different moisture

(with thermal neutron cutoff)



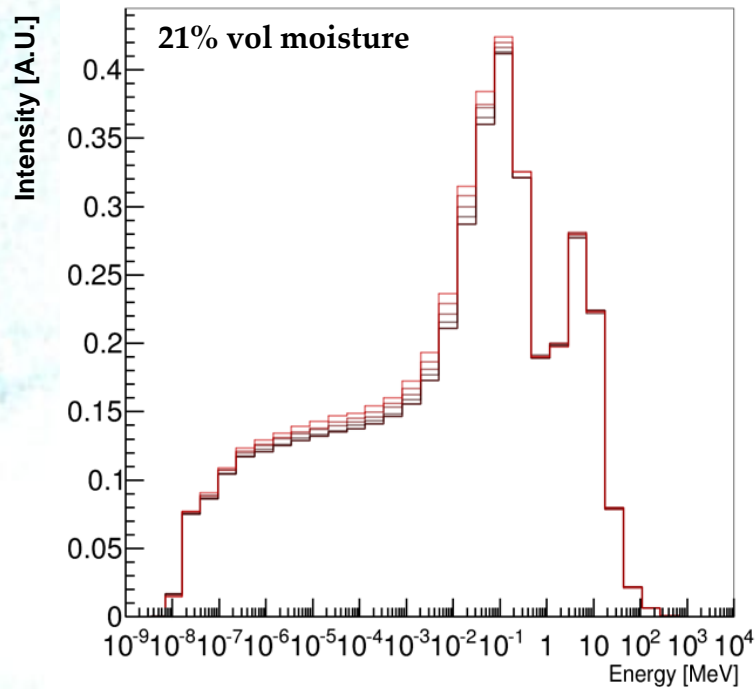
Neutron spectra for soil of different moisture

(with thermal neutron cutoff)



Neutron spectra for different humidities

(with thermal neutron cutoff)

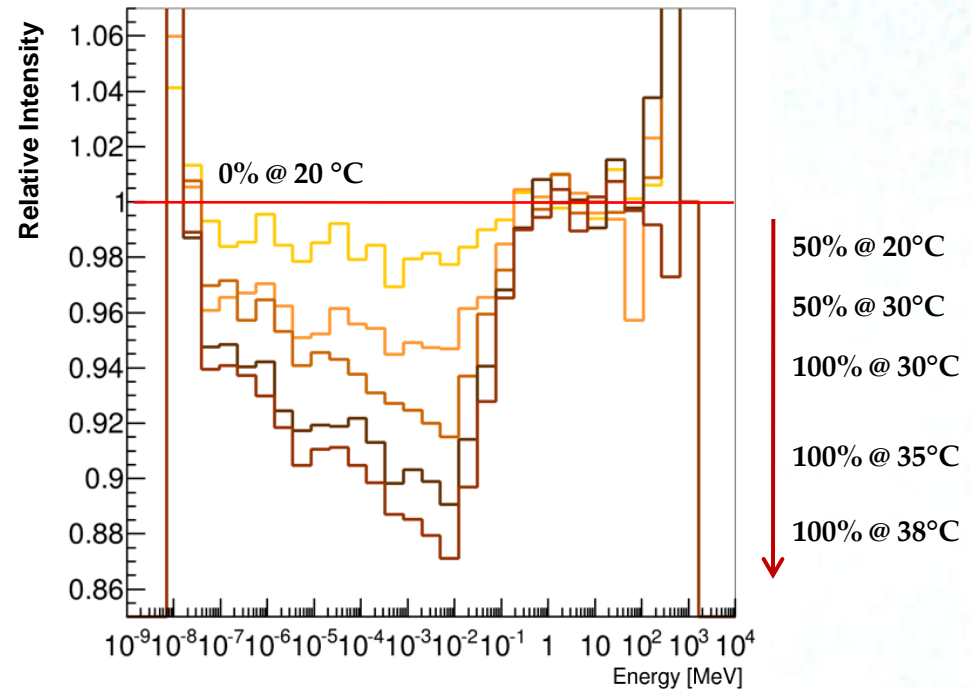
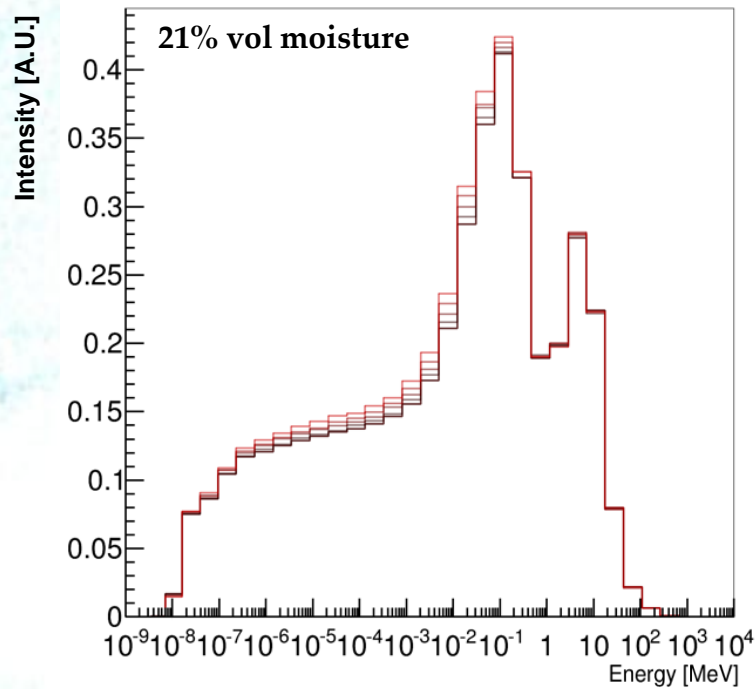


50% @ 20°C
50% @ 30°C
100% @ 30°C
100% @ 35°C
100% @ 38°C

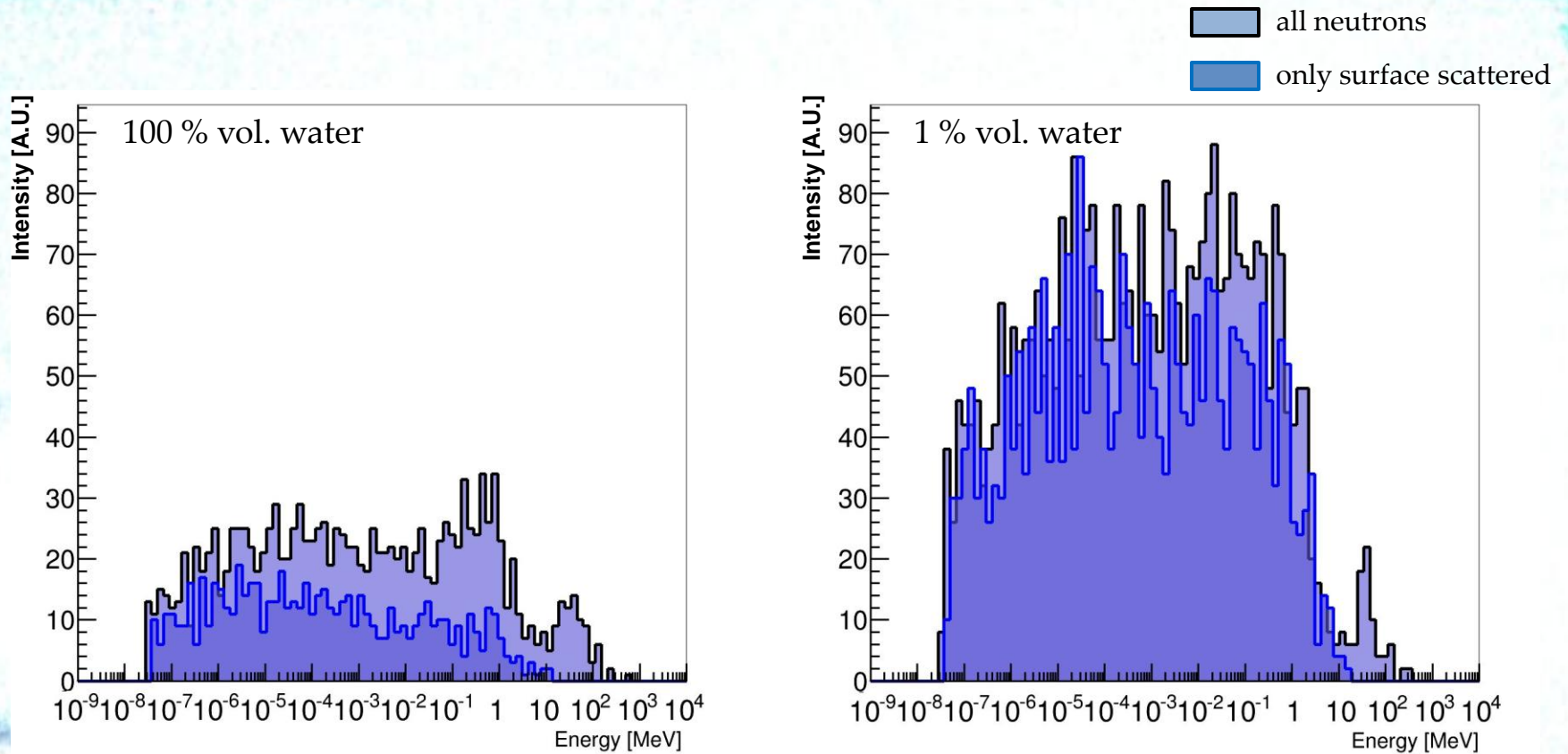
↓

Neutron spectra for different humidities

(with thermal neutron cutoff)

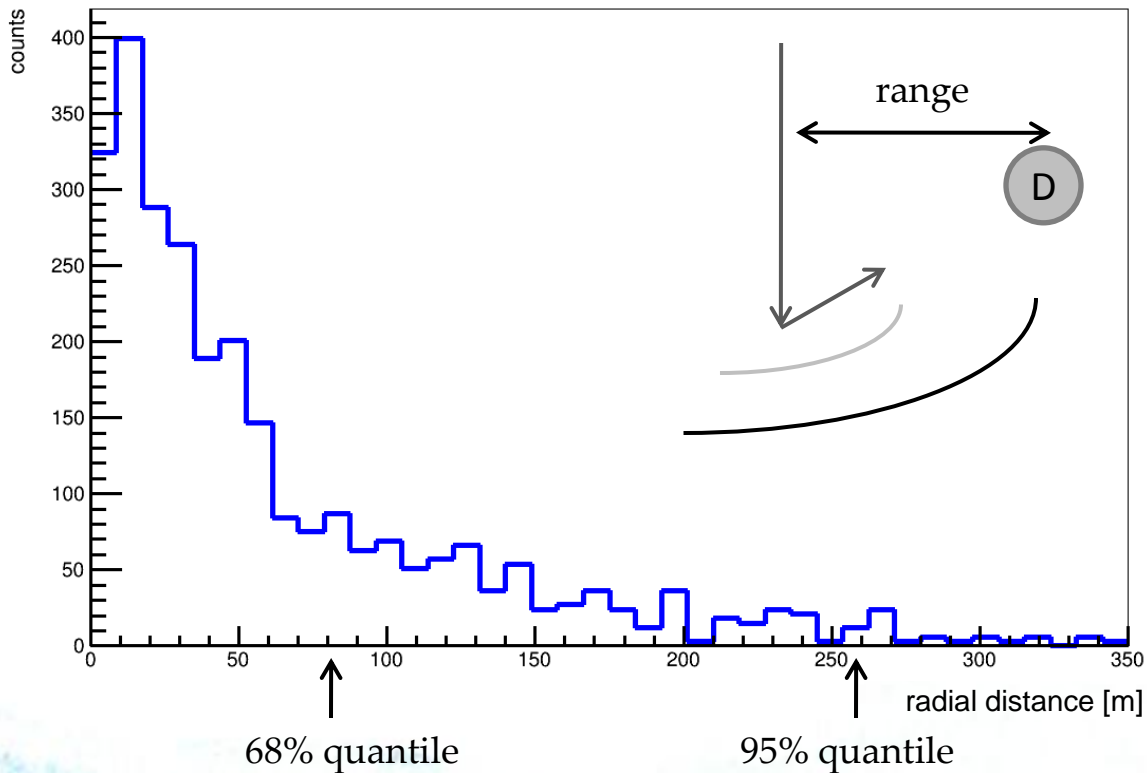


Neutron spectra of a simulated Detector



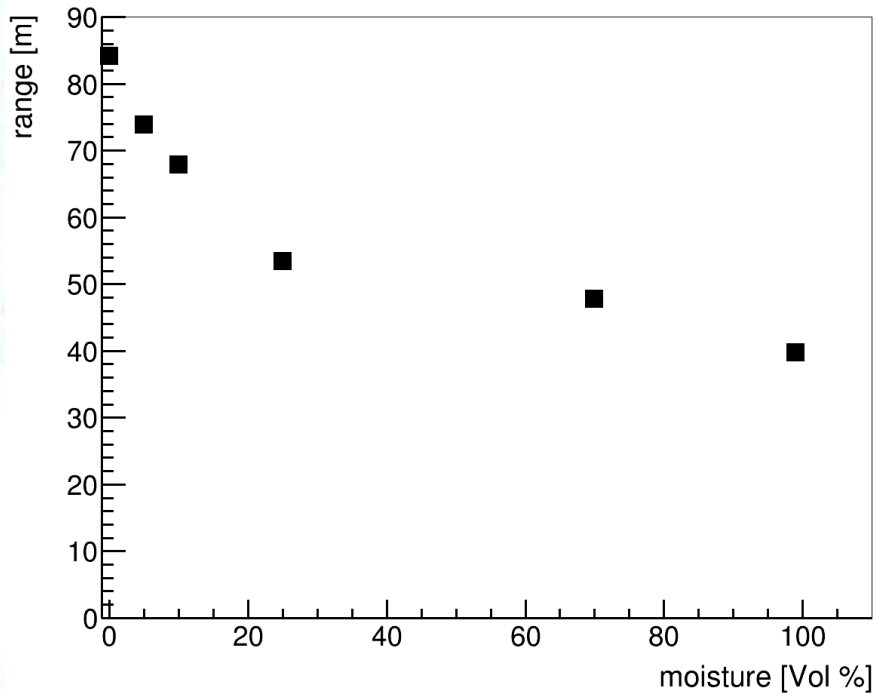
Range distribution of scattered neutrons

Water Content: 0.05, Total entries 2829

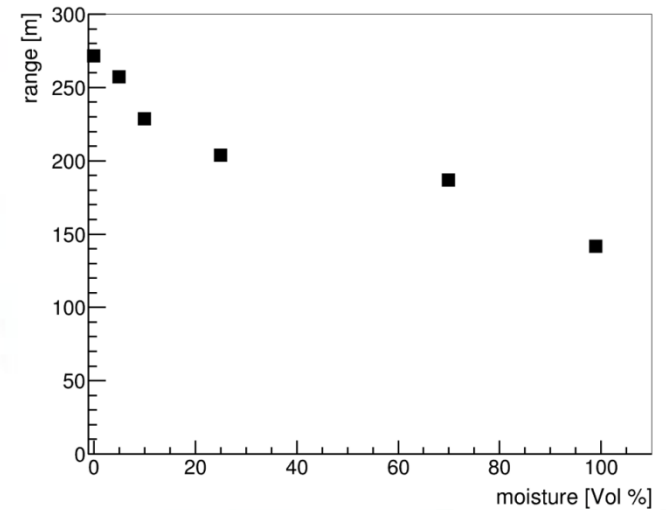


Range of the cosmic neutron probe

Radius of 68% of the neutrons ($Q_{0.68}$)

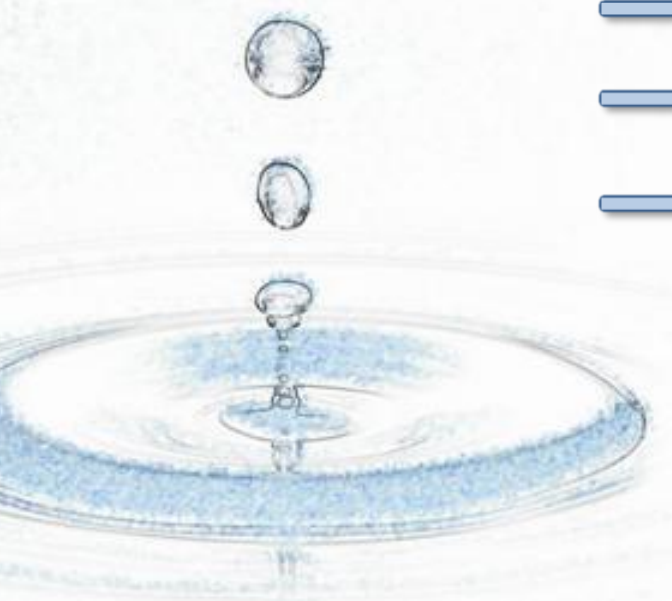


Radius of 95% of the neutrons ($Q_{0.95}$)



Concluding...

Cosmic ray induced neutrons provide a probe for soil moisture



[If the detector is well suited for 10 eV to 100 keV]

[and other – more easy to determine - influences are known]

especially for slight changes at low moisture

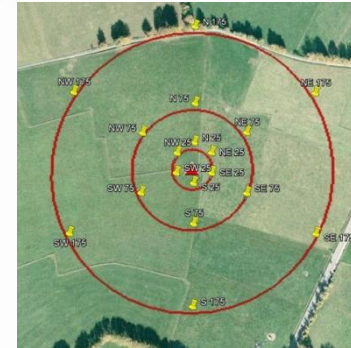
in a radius of about 70 meters at $Q_{0.68}$

Outlook

Understand data collected by actual in-the-field measurements

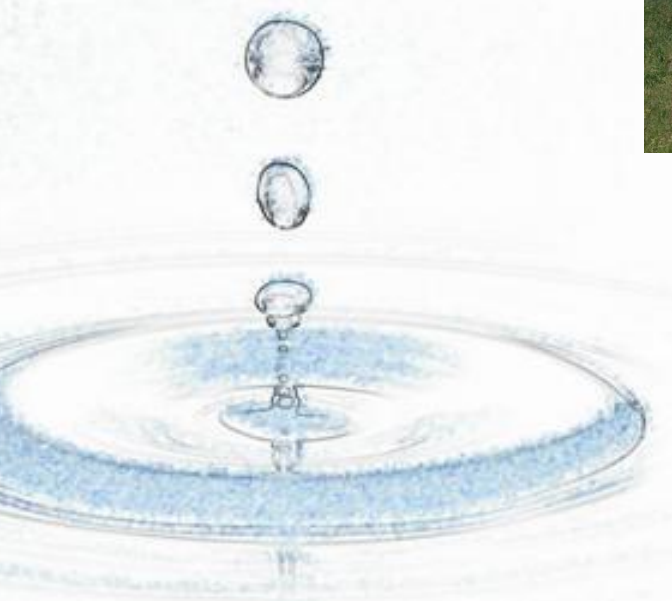


(Neutron Monitor)



(Moisture Sensor Array)

Think of: How should a detector look like?



Probing soil moisture

by cosmic ray induced
neutron showers

- fin-
Thank you

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in collaboration with:

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Helmholtz Center for
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Leipzig

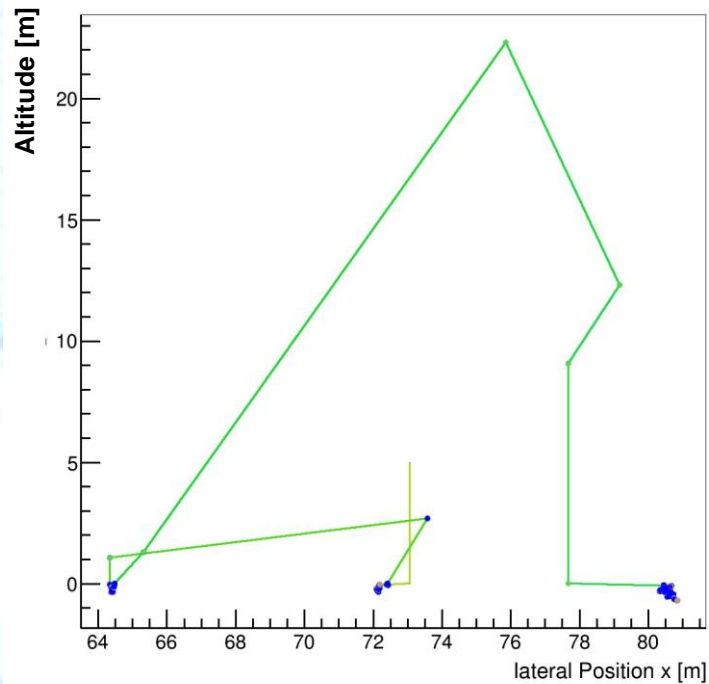




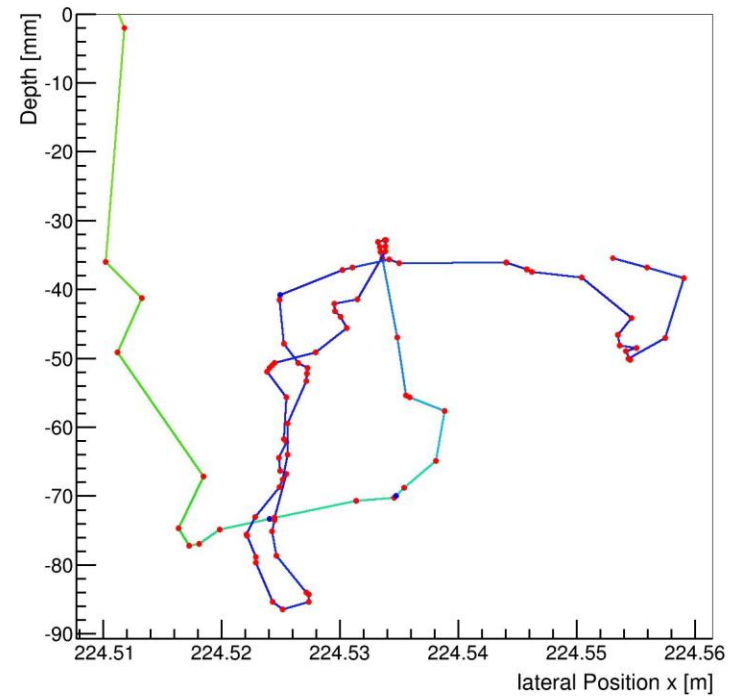
Backup Slides

Example Paths

Neutron scattered off the ground

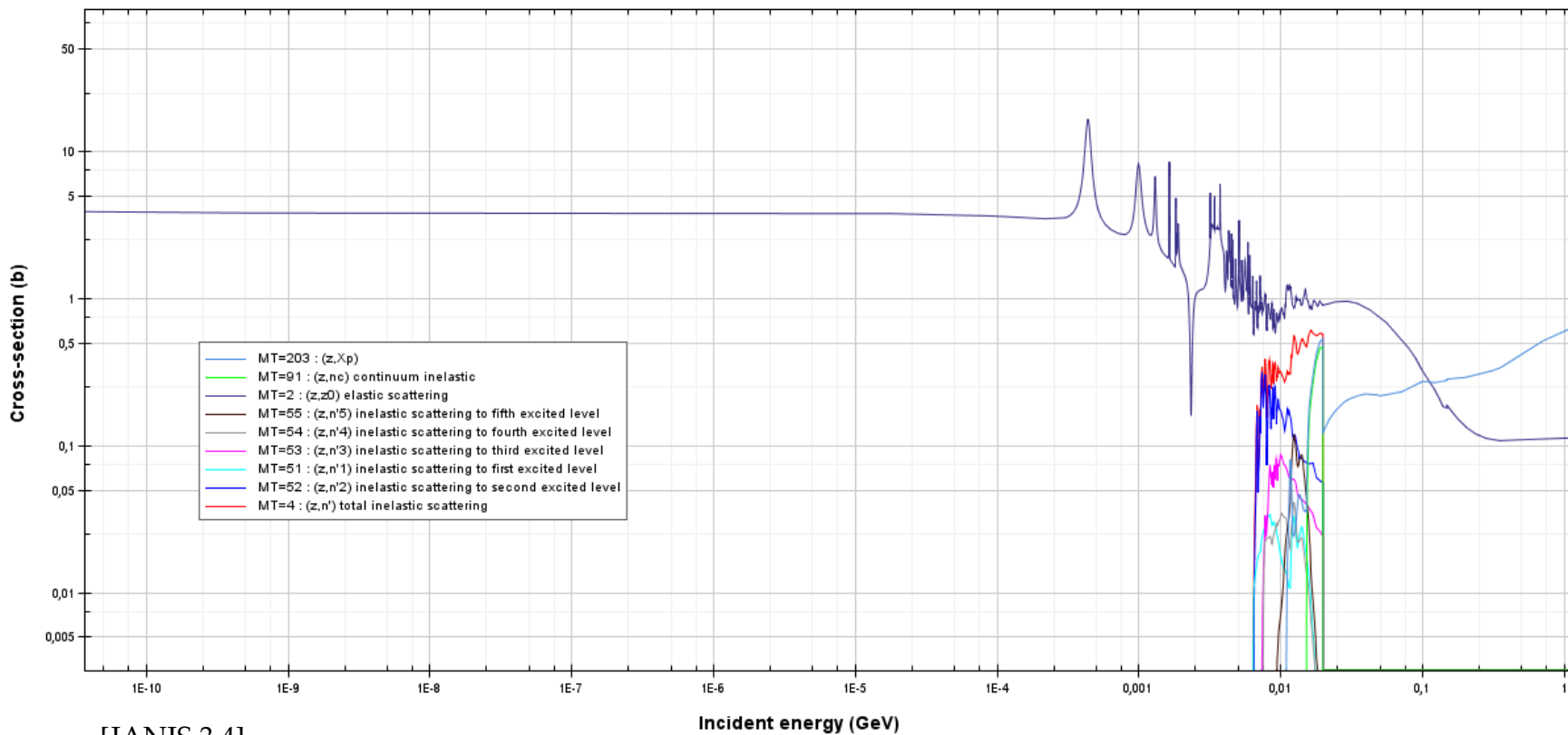


Neutron scattered in water



Example Cross Section

Incident neutron data / JENDL/HE-2007 / O16 // Cross section



[JANIS 3.4]